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Method Development and Validation for Estimation of Liraglutide and it's related substances using RP-HPLC method

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Abstract:
A robust and precise gradient RP-HPLC method was successfully developed and validated for the simultaneous estimation of Liraglutide and its related impurities (Impurity A – Des-acetyl Liraglutide and Impurity B – Glycosylated Liraglutide). Among several trials with varying chromatographic conditions, the optimized method utilized an Inertsil C18 column (250×4.6 mm, 3µm) with a mobile phase consisting of NAH_2PO_4 buffer (pH 4) and methanol**,** employing a gradient elution. The method demonstrated excellent system suitability parameters including resolution (>2), tailing factor (<2), and plate count (>2000) for all analytes. Linearity was established over the range of 40–200 µg/ml for Liraglutide**,** and 4–20 µg/ml for impurities, with correlation coefficients **(**$R^2 > 0.999$**)** indicating excellent linearity. Further, the method showed high precision, with %RSD values well below 2%, and high accuracy, with recovery values ranging from 98–102% at all levels (50%, 100%, and 150%). The LOD and LOQ were found to be well within acceptable limits, confirming the method's sensitivity. Robustness was confirmed through deliberate variations in flow rate and mobile phase composition, which did not significantly impact system performance. The **forced** degradation studies demonstrated that the method is stability-indicating, with all degradation products effectively separated and quantified. Thus, the developed HPLC method is suitable for routine analysis and quality control of Liraglutide formulations and can reliably detect its degradation products and impurities.

Keywords: RP-HPLC method, NAH_2PO_4 buffer, LOD, LOQ, Liraglutide

Introduction

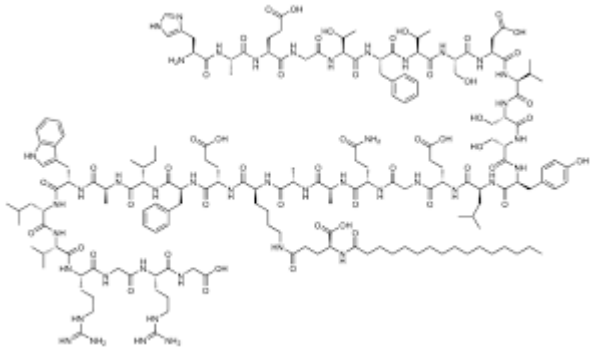

Figure 1: Structure of Liraglutide

Table 1: Drug profile

Property	Information
Molecular Formula	C172H265N43O51
Molecular Weight	3751.2 g/mol
IUPAC Name	(IUPAC name is complex and lengthy, typically not used in common references)
ChemSpider ID	34980716
Polar Surface Area	202.0 Å²
LogP (Octanol/Water)	5.63
Generic Name	Liraglutide
Brand Names	Victoza, Saxenda
Drug Category	GLP-1 receptor agonist
Indications	Type 2 diabetes, chronic obesity
Pharmacology	Mimics GLP-1, increases insulin secretion, decreases glucagon secretion, slows gastric emptying
Potency	Effective at low doses
Tolerability	Generally well-tolerated; common side effects include nausea, vomiting, diarrhea
Contraindications	Personal or family history of medullary thyroid carcinoma, multiple endocrine neoplasia syndrome type 2
Adverse Effects	Nausea, vomiting, diarrhea, pancreatitis, hypoglycemia (when used with insulin or sulfonylureas)
Availability	Prescription only

Materials and Methods

Table 2: Instruments Used

SL. No	Instrument	Model
1	HPLC	WATERS, software: Empower, 2695 separation module, PDA detector.
2	UV/VIS spectrophotometer	LABINDIA UV 3000$^+$
3	pH meter	Adwa – AD 1020
4	Weighing machine	Afcoset ER-200A
5	Pipettes and Burettes	Borosil
6	Beakers	Borosil

Table 3: Chemicals Used

S.No	Chemical	Company Name
1	Liraglutide	Glenmark
3	NAH_2PO_4	FINER chemical LTD
4	Water and Methanol for HPLC	Lichrosolv (MERCK)
5	Acetonitrile for HPLC	MOLYCHEM
6	Ortho phosphoric Acid	MERCK

HPLC METHOD DEVELOPMENT:

Wave length selection:

UV spectrum of 10 µg / ml Liraglutide in diluent (mobile phase composition) was recorded by scanning in the range of 200nm to 400nm. From the UV spectrum wavelength selected as 228nm. At this wavelength both the drugs show good absorbance.

PREPARATION OF MOBILE PHASE:

Preparation of Mobile Phase A (NAH2PO4 PH4):

Weigh and transfer accurately 6.4g of NAH2PO4 in 1000ml water and mix. Adjust the PH to 4.Filter the solution through 0.45µm membrane filter paper and degas it.

Preparation of mobile phase B (MEOH):

MEOH

Diluent Preparation:

MEOH: NAH2PO4.

PREPARATION OF STANDARD SOLUTION:

Standard Solution Preparation:

Accurately weigh and transfer 20 mg working standard into a 20 ml clean dry volumetric flask add about 7 mL of Diluent and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution)

Further pipette 1.2ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Impurity Solution Preparation:

Accurately weigh and transfer the equivalent weight of 2mg of Impurity -A and 2mg of Impurity-B into a 20 ml clean dry volumetric flask add about 7 mL of Diluent and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution)

Further pipette 1.2 ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Procedure:

Inject 20 µL of the standard, sample into the chromatographic system and measure the areas for peaks and identify the impurities known and unknown.

SYSTEM SUITABILITY:

Tailing factor for the peaks in Standard solution should not be more than 2.0

Theoretical plates for the peaks in Standard solution should not be less than 2000.

Resolution for the peaks in standard solution should not be less than 2.

Calculation: (For Liraglutide)

$$\%\,Assay = \frac{AT}{AS} * \frac{WS}{DS} * \frac{DT}{WT} * \frac{Average\ weight}{Label\ Claim} * \frac{P}{100} * 100$$

Where:

AT = average area counts of sample preparation.

AS = average area counts of standard preparation.

WS= Weight of working standard taken in mg.

P = Percentage purity of working standard LC = Label Claim mg/ml.

Validation parameters:

LINEARITY:

Preparation of stock solution:

Accurately weigh and transfer 20 mg of Liraglutide, 2mg of impurity A and 2mg of impurity B working standard into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution)

Preparation of Level – I (40ppm of Liraglutide, 4ppm Imp-A and 4ppm Imp-B):

0.4ml of stock solution has taken in 10ml of volumetric flask dilute up to the mark with Diluents.

Preparation of Level – II (80ppm of Liraglutide, 8ppm Imp-A and 8ppm Imp-B):

0.8ml of stock solution has taken in 10ml of volumetric flask dilute up to the mark with Diluents.

Preparation of Level – III (120ppm of Liraglutide,12 ppm Imp-A and 12ppm Imp-B):

1.2ml of stock solution has taken in 10ml of volumetric flask dilute up to the mark with Diluents.

Preparation of Level – IV (160ppm of Liraglutide, 16ppm Imp-A and 16ppm Imp-B):

1.6ml of stock solution has taken in 10ml of volumetric flask dilute up to the mark with Diluents.

Preparation of Level – V (200ppm of Liraglutide, 20ppm Imp-A and 20ppm Imp-B):

2.0ml of stock solution has taken in 10ml of volumetric flask dilute up to the mark withDiluents.

Procedure:

Inject each level into the chromatographic system and measure the peak area. Plot a graph of peak area versus concentration (on X-axis concentration and on Y-axis Peak area) and calculate the correlation coefficient.

PRECISION:

Preparation of Standard Solution:

Accurately weigh and transfer 20mg of Liraglutide working standard, 2mg of impurity A and 2mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Procedure:

The standard solution was injected for six times and measured the area for all six injections in HPLC. The %RSD for the area of six replicate injections was found to be within the specifiedlimits.

Intermediate precision/ruggedness:

To evaluate the intermediate precision (also known as Ruggedness) of the method, Precision was performed on different day within the laboratory.

Preparation of Standard Solution:

Accurately weigh and transfer 20mg of Liraglutide working standard, 2mg of impurity A and 2mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Procedure: The standard solution was injected for six times and measured the area for all six injections in HPLC. The %RSD for the area of six replicate injections was found to be within the specified limits.

Accuracy:

For accuracy determination, three different concentrations were prepared separately i.e. 50%, 100% and 150% for the analyte and chromatograms are recorded for the same.

Preparation of Standard Solution:

Accurately weigh and transfer 20mg of Liraglutide working standard, 2mg of impurity A and 2mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Preparation Sample solutions:

For preparation of 50% solution (With respect to target Assay concentration):

Accurately weigh and transfer 10mg of Liraglutide working standard, 1mg of impurity A and 1mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution) Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

For preparation of 100% solution (With respect to target Assay concentration): Accurately weigh and transfer 20mg of Liraglutide working standard, 2mg of impurity A and 2mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

For preparation of 150% solution (With respect to target Assay concentration):

Accurately weigh and transfer 30mg of Liraglutide working standard, 3mg of impurity A and 3mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Procedure:

Inject the standard solution, Accuracy -50%, Accuracy -100% and Accuracy -150% solutions. Calculate the Amount found and Amount added for Liraglutide and calculate the individual recovery and mean recovery values.

Limit of detection:

Preparation of Liraglutide solution:

Preparation of 0.04µg/ml solution:

Accurately weigh and transfer 20mg of Liraglutide working standard into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution)

Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Further pipette 0.1ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Further pipette 0.35ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Preparation of IMP-A solution:

Preparation of 0.38µg/ml solution:

Accurately weigh and transfer 2mg of impurity A into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution)

Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Further pipette 2.5ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Further pipette 1.28ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Preparation of IMP-B solution:

Preparation of 1.13µg/ml solution:

Accurately weigh and transfer 2mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Further pipette 3ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Further pipette 3.13ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

LIMIT OF QUANTIFICATION:

Preparation of Liraglutide solution:

Preparation of 0.12µg/ml solution:

Accurately weigh and transfer 20mg of Liraglutide working standard into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Further pipette 0.1ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Further pipette 1ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Preparation of IMP-A solution:

Preparation of 1.29µg/ml solution:

Accurately weigh and transfer 2mg of impurity A into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution). Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents.

Further pipette 4ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Further pipette 2.68ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

Preparation of IMP-B solution:

Preparation of 3.85µg/ml solution:

Accurately weigh and transfer 2mg of impurity B into a 20ml clean dry volumetric flask add Diluents and sonicate to dissolve it completely and make volume up to the mark with the same solvent. (Stock solution) Further pipette 1.2ml of the above stock solution into a 10ml volumetric flask and dilute up to the mark with Diluents. Further pipette 6ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent. Further pipette 5.35ml of the above stock solutions into a 10ml volumetric flask and dilute up to the mark with diluent.

ROBUSTNESS:

As part of the Robustness, deliberate change in the Flow rate, Mobile Phase composition, Temperature Variation was made to evaluate the impact on the method.

The flow rate was varied at 0.8 ml/min to 1.2 ml/min.
Standard solution 120µg/ml of Liraglutide, 12µg/ml of IMP-A and 12µg/ml of IMP-B prepared and analyzed using the varied flowrates along with method flow rate.

The Organic composition in the Mobile phase was varied from 40% to 60%
120µg/ml of Liraglutide, 12µg/ml of IMP-A and 12µg/ml of IMP-B prepared and analyzed using the varied Mobile phase composition along with the actual mobile phase composition in the method.

Result and Discussion

System suitability

Trial 1:

Chromatographic conditions:

Instrument used : Waters HPLC with auto sampler and PDA detector.
Temperature : Ambient (25° C)
Mode of separation : Gradient mode
Column : Platisil ODS (4.6*250mm, 5µ)
Mobile phase: KH2PO4 ph 3.0 (M-A), Acetonitrile (M-B)
Flow rate : 1.0ml per min
Wavelength : 246 nm
Injection volume : 20 µl
Run time : 10 min.

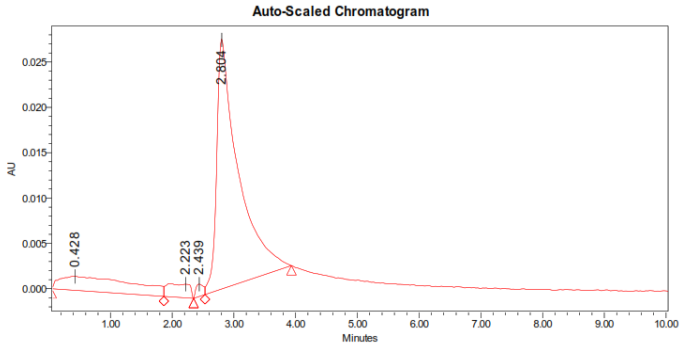

Fig.2: System suitability

Peak Results

	Name	RT	Area	Height	Amount	Units	USP Resolution	USP Tailing	USP Plate Count
1		0.428	138612	1534					
2		2.223	37916	1501					
3		2.439	11388	1368					
4		2.804	674890	27625				2.38	360.83

OPTIMIZED CHROMATOGRAPHICCONDITIONS

Instrument used :High performance liquid chromatography equipped with
Auto Sampler and PDA
Temperature : 25^0C
Mode : Gradient
Column : Inertsil C18, (250×4.6mm, 3µm)
Buffer : NAH2PO4 PH4
Mobile phase : NAH2PO4 PH4: MEOH
Diluent : Water: MEOH: 1N NaoH
Flow rate : 1.0 ml per min
Wavelength : 246 nm
Injection volume : 10 µl
Run time : 25 min.

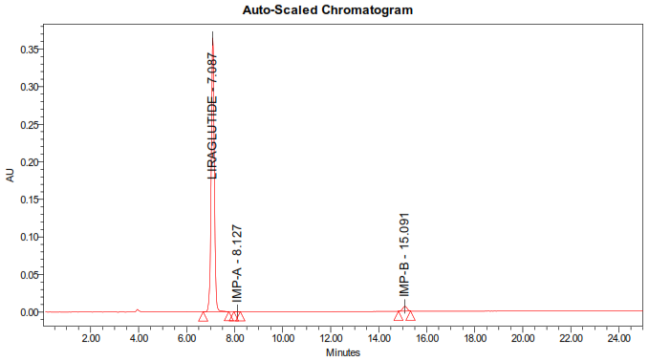

Fig.3: Optimized Chromatogram

Impurity A-Des aceyl Liraglutide
Impurity B-Glycosylated Liraglutide
STANDARD SOLUTION PREPARATION

Weigh and transfer accurately 20mg of Liraglutide and in 20ml distilled Methanol and Spike 2mg of Impurity A-Des aceyl Liraglutide and 2mg of Impurity B-Glycosylated Liraglutide ,sonicate for 5 min and Filter the solution through 0.45µm membrane filter.

Procedure:

Inject 20µl of the standard solution and observe the system suitability parameters are passed.

Conclusion: The System suitability parameters are within the acceptance limits.

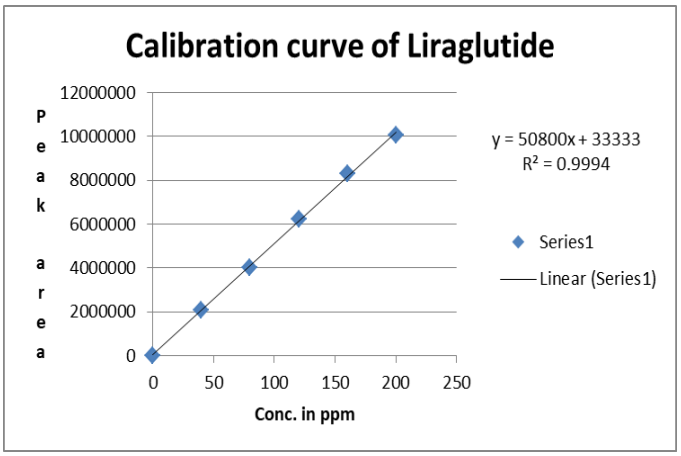

Fig.4: Calibration graph for Liraglutide

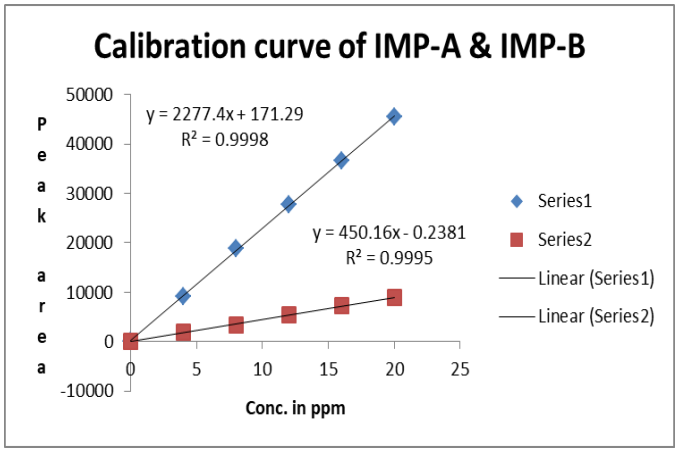

Fig.5: Calibration graph for Impurity A and B

Table 4: Analytical performance parameters of Liraglutide, Impurity A and B

Parameters	Liraglutide	Impurity A	Impurity B
Slope (m)	50800	2277.4	450.16
Intercept (c)	33333	171.29	0.2381
Correlation coefficient (R^2)	0.9994	0.9998	0.9995

Table 5: Results of Precision for Liraglutide, Imp-A & B

Injection	Areas	Areas	Areas
Injection-1	6214571	27417	5417
Injection-2	6214578	27458	5463
Injection-3	6235417	27110	5421
Injection-4	6233654	27389	5489
Injection-5	6214785	27541	5420
Injection-6	6239874	27231	5433
Average	6225480	27358	5441
Standard Deviation	10992.33	158.47	29.215
%RSD	0.2	0.6	0.5

Table 6: Results of Intermediate precision for Liraglutide

Injection	Areas	Areas	Areas
Injection-1	6321458	28544	5563
Injection-2	6395478	28554	5547
Injection-3	6321587	28631	5489
Injection-4	6399851	28641	5412
Injection-5	6320145	27999	5533
Injection-6	6320147	28514	5537
Average	6346444	28481	5514
Standard Deviation	39703.86	241.17	55.511
%RSD	0.6	0.8	1.0

Table 7: Accuracy (recovery) data for Liraglutide

%Concentration Liraglutide (at specification Level)	Area*	Amount Added(mg)	Amount Found(mg)	% Recovery	Mean Recovery
50%	3088741	10	9.92	99.4	99.0
100%	6185471	20	19.86	99.3	
150%	9215741	30	29.59	98.6	

%Concentration Impurity A (at specification Level)	Area*	Amount Added(mg)	Amount Found(mg)	% Recovery	Mean Recovery
50%	13552	1	0.99	98.7	98.8
100%	26987	2	1.96	98.2	
150%	41047	3	2.99	99.6	

%Concentration Impurity B (at specification Level)	Area*	Amount Added(mg)	Amount Found(mg)	% Recovery	Mean Recovery
50%	2671	1	0.98	98.2	98.5
100%	5368	2	1.98	98.9	
150%	7993	3	2.95	98.2	

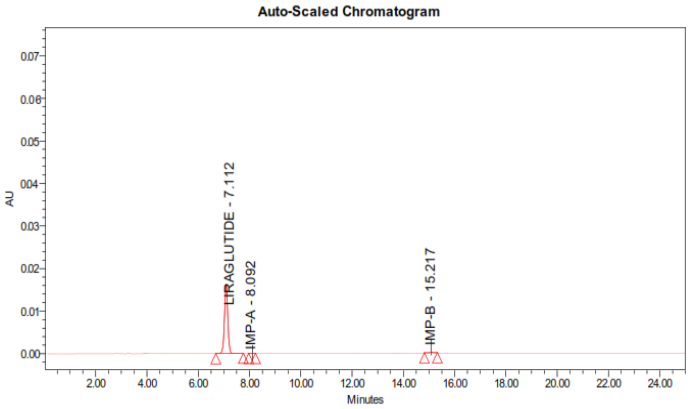

Fig.6: Chromatogram of Liraglutide showing LOD

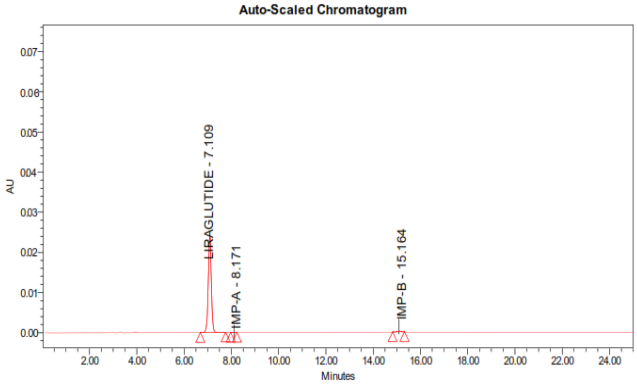

Fig.7: Chromatogram of Liraglutide showing LOQ

Conclusion

The proposed HPLC method was found to be simple, specific, precise, accurate, rapid and economical for simultaneous estimation of Liraglutide and it's Related substances using RP-HPLC method in pharmaceutical dosage form. The developed method was validated in terms of accuracy, precision, linearity, robustness and ruggedness, and results will be validated statistically according to ICH guidelines. The Sample recoveries in all formulations were in good agreement with their respective label claims. Hence the suggested RP-HPLC method can be used for routine analysis of Liraglutide and it's Related substances in API and Pharmaceutical dosage form

Conflict of Interests

The authors declare no conflict of interest

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AI Tool Declaration

The authors declare that no AI and related tools are used to write the scientific content of this manuscript.

Data Availability

Data will be available on request

References

[1] Drucker DJ. The role of gut hormones in glucose homeostasis. J Clin Invest. 2007;117(1):24-32.

[2] Knudsen LB, Lau J. The discovery and development of liraglutide and semaglutide. Front Endocrinol (Lausanne). 2019;10:155.

[3] Frokjaer S, Otzen DE. Protein drug stability: a formulation challenge. Nat Rev Drug Discov. 2005; 4(4): 298-306.

[4] Nagarajan G, Govardhan B, Ramana B. V, Sujatha K, Rubina S, Arundathi T and Soumya R, "Development and Validation of a RP- HPLC Method for Simultaneous Estimation of Enalapril maleate and Ramipril in Bulk and Tablet Dosage Form", Der Pharmacia lettre. 2013; 5(1):69-76.

[5] Khameneh B, Iranshahy M, Soheili V, Fazly Bazzaz BS. Peptides as a novel generation of anti-biofilm agents in medical sciences. Peptides. 2016; 78:91-101.

[6] Gilar M, Olivova P, Daly AE, Gebler JC. Two-dimensional separation of peptides using RP-RP-HPLC system with different pH in first and second separation dimensions. J Sep Sci. 2005; 28(14):1694–1703.

[7] International Conference on Harmonisation. ICH Q2(R1): Validation of Analytical Procedures: Text and Methodology. ICH Harmonised Tripartite Guideline. 2005.

[8] International Conference on Harmonisation. ICH Q3A(R2): Impurities in New Drug Substances. 2006; ICH Q3B(R2): Impurities in New Drug Products. 2006.

[9] Pedaprolu JN, Bonthu MG, Vatchavai BR, Kamatham SS, Kolli S, Kapuganti ANJ. A new stability-indicating and validated RP-HPLC method for the estimation of liraglutide in bulk and pharmaceutical dosage forms. Eurasian J Anal Chem. 2017; 12(2):31–44.

[10] Sharma V, Patel A, Shah P. Establishment of stability-indicating purity method based on the stress degradation behaviour of human GLP-1 analog liraglutide. Indian J Pharm Sci. 2023;85(4):1068–1076.

[11] Shah R, Patel J, Parmar R, Vora S. Simultaneous estimation and impurity profiling of liraglutide using RP-HPLC: A validated stability-indicating method. J Pharm Anal. 2024; 14(2):115–124.

[12] Satyanarayana PV, Madhavi AS. Validated RP-HPLC method for the estimation of liraglutide in tablet dosage. Int J Sci Invent Today. 2012; 1:17-26.

[13] Balaji Nagarajan, Gunasekar Manoharan , Ganapathy Narayanan Shanmugam , Nataraj Palaniyappan and Abhinav Yarragunta . Ultra-performance liquid chromatography determination of related compounds of molindone in drug substances. European Journal of Chemistry. 2022, 13 (2): 180-185.

[14] Nataraj Palaniyappan*, Satish Pavuluri, T. Venkatachalam. Method development and validation of rp-hplc method for estimation of sulfamethoxazole and trimethoprim oral suspension usp. Journal of Population Therapeutics & Clinical Pharmacology. 2024: 31(6).24-30.

[15] Pedaprolu JN, Bonthu M, Vatchavai B, Kamatham SS, Kolli S, Kapuganti AN. A new stability-indicating and validated RP-HPLC method for the estimation of liraglutide in bulk and pharmaceutical dosage forms. Eur J Anal Chem. 2017; 12(2):31-44.

[16] Asmathi G, Sreekanth A, M Pradeep Kumar, Development, Validation and simultaneous estimation of Sulfamethoxazole and Trimethoprim by RP-HPLC method, Himalayan Journal of Health Sciences, 2022, Volume-7, Issue -4, 10-29.

[17] Dong S, Gu Y, Wei G, Si D, Liu C. Determination of liraglutide in rat plasma by a selective liquid chromatography-tandem mass spectrometry method: Application to a pharmacokinetics study. Journal of Chromatography B. 2018; 1091: 29-35.

[18] P. Nataraj, M. Ravisankar, M. Vijayakumar, M. Sivagamy, G. P. Senthilkumar (2025). Analytical Method Development and Validation to Assess the Particle Size Distribution in Azithromycin Oral Suspension 200mg/5ml. Saudi J Med Pharm Sci, 11(10): 949-952.

[19] Chavoshi F, Mirjalili SZ, Mohammadi A, Amini M, Somsen GW, Shirangi M. Forced Degradation Products of Liraglutide: A Comparative Study of Similarity Between Originator and Analogue Version by Liquid Chromatography–Mass Spectrometry. International Journal of Peptide Research and Therapeutics. 2024; 30(3):1-3.

[20] Oh HS, Choi M, Lee TS, An Y, Park EJ, Kim TH, Shin S, Shin BS. Pharmacokinetics and brain distribution of the therapeutic peptide liraglutide by a novel LC–MS/MS analysis. Journal of Analytical Science and Technology. 2023; 14(1):19.